HYDROGEOLOGICAL INVESTIGATIONS CARRIED OUT IN MOUNT KOZUF FOR THE WATER SUPPLY SYSTEM OF THE TOWN OF GEVGELIJA

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Abstract

The structural type of porosity in Mt. Kozuf made possible the formation of several types of aquifers: phreatic, complex, fracture and karst.

Hydrogeological investigations carried out indicate that the issue of good water supply for the needs of the town of Gevgelija can be solved by the use of underground waters of the karst aquifers formed in the karstified Triassic stratified and massive limestones and Precambrian marbles and cipolines.

Kew words: Triassic stratified and massive limestones, karts aquifers, spring, Huma 1, Huma 2, Sermenin, Gevgelija.

INTRODUCTION

Detailed hydrogeological investigations were carried out in Mt. Kozuf in order to solve the issue of water supply of Gevgelija located close to the mountain. The presence of a large number of Triassic limestones indicate that the terrain should be investigated in detail and the hydrogeological characteristics defined in order to find the most favourable solution for the water supply system of the town.

GEOGRAPHIC AND GEOMORPHOLOGICAL CHARACTERISTICS

The area under investigation is part of Mt. Kozuf situated in the south most part of the Republic of Macedonia close to the border with Greece. It occupies some 120 km^2.

The terrain is mountainous and situated 600 to 2000 m above sea level. It is not densely populated and the infrastructure is poor. The relief is quite pronounced with several peaks. The geomorphological characteristics are the result of neogene tectonic movements when the Gevgelija valey and its marginal sections formed. Exogen erosion processes resulted in the final reshaping of the area forming the hydrogeological net and occurrences.

Karsts occurring in several separate localities bear specific features. The one near the village of Huma, occupying a smaller area, has typical surface and underground forms and specific hydrographic occurrences. Radovanovic (1929) defines it as holokarts.

CLIMATIC AND HYDROGRAPHIC CHARACTERISTICS

Although the terrain is part of the Mediterranean area, its high mountains make the climate continental mountainous, particularly in parts higher than 1000 meters.

Hydrometeorological measurements show that precipitation in the highest parts of the terrain range from 700 to 1100 mm a year. The villages of Huma and Sermeni, regarded as the most important sites in terms of their water reserves, have average annual rainfalls of 900 to 1100 mm.

The terrain has a net of surface flows the most important being the Rivers Dosnica, Sermeninska, Konska and Sarandarska. The rivers and their tributaries have surface flows during the whole year. A number of smaller tributaries dry out during the summer and autumn.

GEOLOGIC AND TECTONIC COMPOSITION OF THE TERRAIN

The geology of the terrain consists of several stratigraphic complexes: Precambrian metamorphic, Early Paleozoic metamorphic rocks, Mesozoic sedimentary and igneous and Tertiary sedimentary and igneous rocks.

The complex of Precambrian metamorphic rocks is present as fine-grained amphibole-muscovite gneisses, marbles and cipolines.

The Earlier Paleozoic complex is present as rocks of low degree of crystallinity than the Precambrian. It is made up of phylites and various schists such as epidote, chlorite, sericite, quartz and cipolines, argilloschists, marbles and metamorphosed limestones as well as meatmorphosed quartz-porphyry. The lithological composition in the Early Paleozoic rocks allows the distinguishment of several horizons: a horizon of phylites and phylite schists, a horizon of cipolines and schists; a horizon of phylites, argiloschists and sandstones; a horizon of metamorphosed quartz porphyry and a horizon of phylites, quartz schists and marbelised limestones, cipolines and marbles.

The complex of Mesozoic rocks is present as Triassic sediments, gabbros, diabases, quartz-keratophyre and variegated clayey schists, quartzites and sandstones. Three facies have been distinguished among the Triassic sediments:

- a facies of variegated clayey schists cherts and sandstones,
- a facies of massive stratified limestones,
- a facies of sandstones, clayey schists, quartzites and sandstones.

The Tertiary complex is made up of andesites and andesite tuffs, spring tufa with gravel, alluvial terrace sediments, deluvial sediments and alluvial fluvial sediments.

According to the tectonic regional setting of Macedonia the terrain belongs to the Vardar zone (Arsovski (1997).

HYDROGEOLOGICAL CHARACTERISTICS OF THE TERRAIN

The first data about the hydrology of the terrain and the holocaust of Huma can be found in Radovanovic (1929). Later regional hydrogeological investigations were carried out for the map the scale 1:100 000.

Based on the structural type of porosity the following types of aquifers have been distinguished:

- phreatic,
- complex,
- fracture and
- karts.

Phreatic aquifers

Phreatic aquifers have formed in sediments with intergranular prorosity present as alluvial fluvial sediments found along valley and river courses as present day layers, alluvial terrace sediments and deluvial detrituses. Based on their yield the terrains with phreatic aquifers are divided into:

Very yielding terrains with yield exeeding 10 l/s such as the alluvial sediments in the River Belica or Sermeninska River.

Failry good yielding terrains with 1.0 to 10 l/s that include all clastic sediments with intergranular porosity such as alluvial terrace sediments in the Dosnica river bed, the alluvial terrace sediments between the village of Konsko and Milisin and the deluvial sediments near Brnje.

Low yielding terrains with yield of 1 l/s. These include the deluvial sediments in Krsko Pole, Brce and the two whirlpools in the village of Huma and the vicinity.

Complex aquifers

Complex aquifers have formed in rocks with intergranular and fracture-karts porosity. The yield in these terrains is from 0.1 to 1 l/s. Complex aquifers occur in spring tufa and river detrituses of gravel along the River Sermeninska, downstream the spring of the karst aquifer.

Fracture aquifer

Rocks of fracture porosity in the area under investigation are widespread and heterogenous. They are highly fractured and located at great depth. The rocks contain a large number of springs. Along the Konska River and Smrdliva Voda there are a numbre of mineral springs. Their yield seldom exeeds 1 l/s. Based on their yield the terrains of fracture type aquifers are devided into:

Waterless terrains made up of Paleozoic rocks present as phylites and phylite schists, phylites, argoloschists and sandstone phylites, quartz schists and marbelised limestones, cipolines and marbles, Triassic variegated clayey schists, quartzites, cherts and sandstones, Jurassic gabbro, diabases and quartzkeratophyre and Quaternary andsites and aglomerative-breccia tuffs.

Springs can rarely be found in waterless terrains, if any, their yield is lower than 0.1 l/s.

Low yielding terrains are those of Jurrasic quartzkeratophyre and gabbros, Triassic sandstones, clayey schists, quartzites and cherts and Paleozic quartz-porphyries, phylites, quartz schists and marbelised limestones, cipolines and marbles, cipolines and schists, phylite and phylite schists and muscovite gneisses. The yield in the terrains is from 0.1 to 1 l/s.

Good yielding terrains are present in Jurassic gabbro and Paleozoic quartz-poprhyry, phylites, quarz schsist marbelised limestones, cipolines and marbles, cipolines and schists, phylite and phylite schists and muscovite gneisses. The yield of these springs amounts from 1 to 10 l/s.

Mineral springs

Mineral springs appear in geisses of the fault along the River Konska and in the transversal fault from Milevo Bacilo to Buka. Seven springs of the kind have been found. At Smrdliva Voda mineral waters have been found during drilling explorations.

Mineral water has also been found on the left side of River Konska in Paleozoic quartz porphyry. The yield is from 0.02 to 0.2 l/s. pH is 4.5 - 7.6 and water temperature is from 6 to 13.5^{o}C.

Karst aquifers

Karst aquifers can be found in several localities in karstified Precambrian marbles and cipolines and in Triassic stratified and massive limestones. Karstification and porosity in all carbonate rocks are well developed. This assumption is supported by the absence of perenial surface flows.

Karst springs

Karst springs seldom occur, but are characterised by significant amounts of water. Larger springs can be found in Triassic limestones such as Sermenin, Huma 1 and Huma 2.

The Sermenin springs

The springs at Sermenin (Fig. 1) are characterised by their largest water amounts. They occur in the alluvial sediments of the Rivers Belica and Sermeninska some 1.5 km downstream the village of Sermenin. The main spring (no. 5) yields 320 l/s, as measured on 11 April 1980. The second largest spring (no. 7) located 0.5 km further from the main spring yields 250 l/s. The smallest spring (no. 6) which is located below the main spring yields 1.1 l/s. It is characetrsistic that this spring often migrates downstream and upstream depending on the underground watertable in karts aquifers.

The variability of the spring has been confirmed by measurements carried out on 8 September 1980. The results obtained are as follows:

Table 1. Measurements caried out on 8 September 1980.

	yield l/s
Spring no. 5	53
Spring no. 7	28
left side of River Sermeninska	41
right side of River Sermeninska	17
Total	139

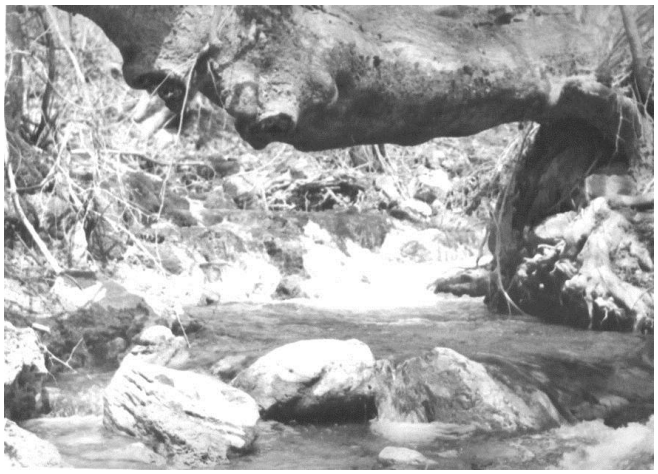

Fig. 1. The River Sermeninska that forms from the Sermenin spring

The Huma 1 spring

Huma 1 is located 1.5 km northwest of the village of the same name. It is the second largest plenteous spring. The springs are located in strongly kartsified Triassic limestones. The main spring (fig. 2) yields 80 to 90 l/s, water temperature being 10°C. Measurements were carried out in April 1980. Downstream the right side of the brook that forms from the spring, as perennial flow during the year, a fault-dam spring covered with deluvium has been determined. The yield in April in the same year was 20 to 30 l/s. The yield of the whole Huma 1 spring amounts to 120 l/s with underground runoff of 10 l/s. Measurements carried out in September in the same year determined 70 l/s - only 10 to 20 l/s less compared to that in April. The total yield of Huma 1 is estimated at 100 l/s. This assumed that it contains a good amount of water necessary for the water supply system of Gevgelija.

The Huma 2 spring

This spring is located some 1.2 km. in karstified Triassic limestones northwest of the village of Huma. The limestones are overlain by gabbros. Two springs have been found there.

In April 1980 the yield of the larger spring was estimated at 50 l/s, whereas in the smaller one at 35 l/s with water temperature of 11°C. The larger spring flows out directly from the limestones (fig. 3) and the lower one from limestone rocks covered by deluvial layer. The yield of Huma 2 is less stable compared with Huma 1. This was confirmed by the measurements in September 1980. The smaller spring was dry at that time. The yield of the larger one amounting to 24 l/s which was three times lower compared with the total amount of water measured in May the same year. It is estimated that there is an underground runoff of some 5 to 10 l/s into the stream detrituses.

All other karst springs in the vicinity of Huma are insignificant, as their total yield does not exceed 1 l/s (according to data from April 1980).

PHYSICAL AND CHEMICAL PROPERTIES OF THE WATER

Hydrogeological investigations were accompanied by chemical studies of the water. The results obtained are given in Tables 2 .

Table 2. Chemical studies of the water.

Locality		Huma 1	Huma 2	Sermenin
Day		2. 07. 1980	2. 07. 1980	2. 07. 1980
pH		7.4	7.3	7.3
Natries	mg/l	0.0015	0.0	0.0
Nitrates	mg/l	0.90	0.9	0.0
Chlorides	mg/l	8	9.0	6.0
$KMnO_4$	mg/l	3.1	2.2	3.4
Dry resedue 105°C	mg/l	210	248	274
Mn	mg/l	0.0	0.0	0.0
Fe	mg/l	0.0	0.0	0.05
Sulphates SO_4	mg/l	39.7	37.78	23.7
Ca	mg/l	20.9	1.6	60.8
Mg	mg/l	20.9	43.68	22.56
F	mg/l	0.178	0.230	0.105
Total hardness dH°		14.16	11.50	11.0

Carbonate hardness dH		10.92	11.48	10.9
Total beta radioactivity	μCi/ml	3.690 h 10^{-8}	0.090 h 10^{-8}	0.122 h 10^{-8}

After the classification of Alekin these waters belong to hydrocarbonates, calcio magnesium waters.

Based on their physical properties the waters are clear, with no odor and taste. The physico-chemical properties indicate that the waters do not contain noxious substances and can be used as drinking water.

POSSIBILITY TO SOLVE THE WATER SUPPLY OF GEVGELIJA

Based on the hydrogeological investigations carried out it can be said that the issue of water supply of Gevgelija with good drinking water can be solved with the capture of the Huma 1 and 2 karts aquifers. Another possible solution is the construction of a catchment gallery in the marbles and cipolines of the Cici and Smrdliva Voda hills.

The Sermenin capture

This capture would include the waters of the three springs denoted as 5, 6 and 7. Their yield in April was about 571 l/s, and in September 139 l/s that can be regarded as annual minimum. With underground runoff of 50 to 60 l/s, it is estimated that the total yield of this spring would amount to 200 l/s. This is an important amount of quality water for Gevgelija.

Spring 5 is situated at peak 640 m, spring 6 at peak 635 m, and spring 7 at peak 700 m.The height is sufficient to bring the waters to Gvgelija via a gravitational route.

The intake of the capture should be performed with greatest narrowing of river valley with an underground reservoir overlying the gabbos, which are the foundation of alluvial fluvial sediments. The thickness of detrituses is from 1 to 12 m and the river is 160 m wide. The hydrogeological section through the catchment at Huma 1 spring is shown in fig. 2.

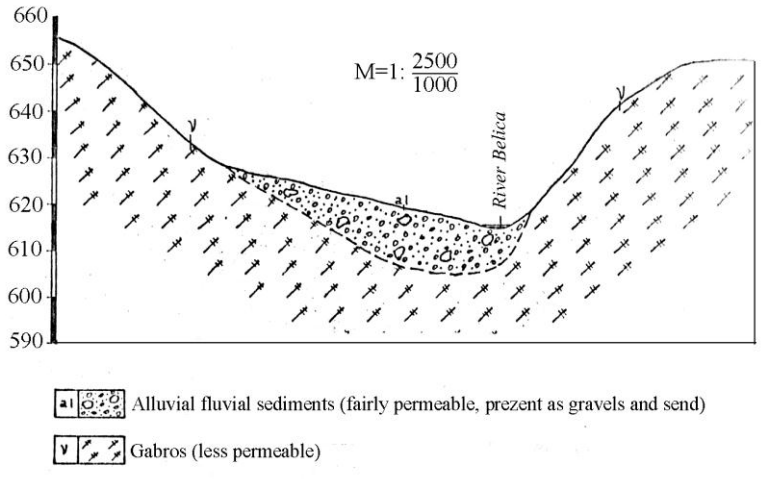

Fig. 2. Hydrogeological section through the Sermenin spring.

Huma 1 and Huma 2 captures

The Huma 1 and 2 karst springs are situated 2 km from one another, some 13 to 15 km from Gevgelija.

The Huma 1 spring

Huma 1 consists of two springs situated 180 to 185 above sea level. The yield of the former in April is 80 to 90 l/s, and of the latter 20 to 30 l/s, the underground runoff being 10 l/s. The yield of the larger spring in September is 70 l/s, only 10 to 20 l/s less than in April. With the upstream smaller spring and underground runoff, the amount of 100 l/s can be expected. As with Sermenin, here also capture would be carried out underground, with the construction of underground reservoir above the gabbros. The hydrogeological section through Huma 1 intake is shown in fig. 3.

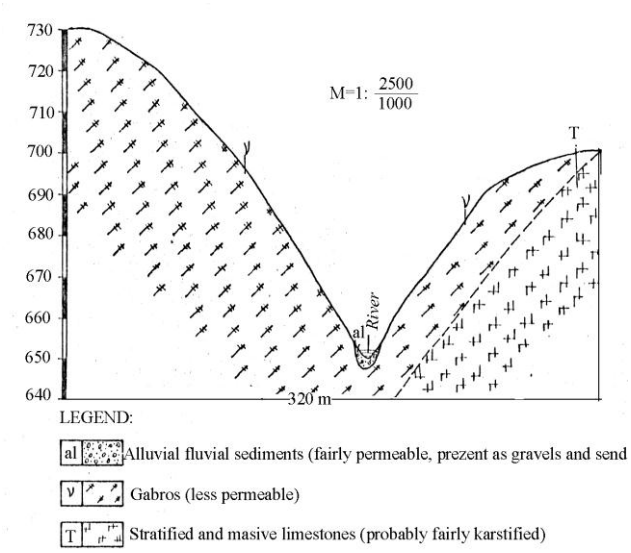

Fig. 3. Hydrogeological section through of the Huma 1 spring.

The Huma 2 spring

The Huma 2 is situated 680 to 700 m above sea level. It consists of two springs.

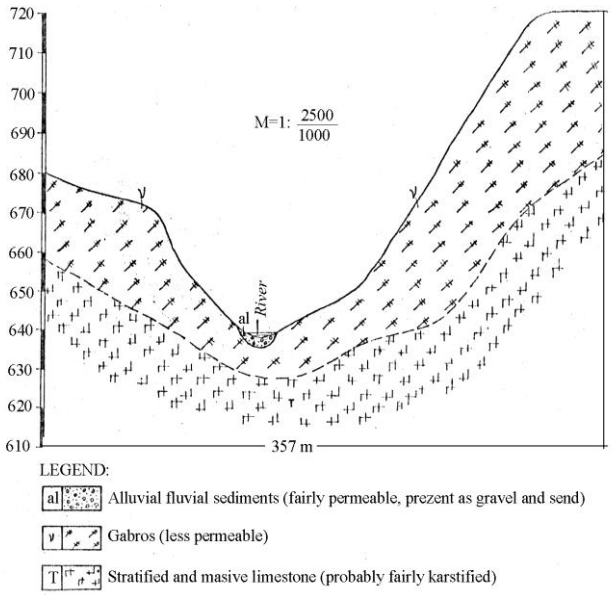

Fig. 4. Hydrogeological section through the intake of Huma 2 spring.

The yield of the upper spring in April amounts to 50 l/s and in the lower 35 l/s. Huma 2 is less stable as proved by measurements carried out in September. In September the yield of the upper spring was 24 l/s, whereas the other dried out completely. With underground runoff in detrituses a total yield of 30 l/s can be expected. The total quantity of water in both Huma 1 and Huma 2 would amount to 130 l/s. The hydrogeological section through the intake of Huma 2 spring is shown in fig. 4.

Catchment gallery in marbles in cipolines above Smrdliva Voda

The hydrogeological characteristics of the Precambrian marbles and cipolines and gneisses at the floor rock make possible the construction of an underground catchment gallery in the Cici hill near Smrdliva Voda (fig. 5). It is recommended the gallery to be 1 000 m long and constructed at 1 000 m above sea level. The 600 m of the gallery would be constructed in waterless gneisses and the other part in cipolines and marbles - a karts spring 500 to 100 m beneath the underground water level. It is assumed that this would yield 150 to 250 l/s of underground water. Prior to the implementation, 250 m and 600 m drill holes should be drilled in order to determine the contact parts between the marbles and cipolines with the gneisses in the floor rock and the degree of karstification.

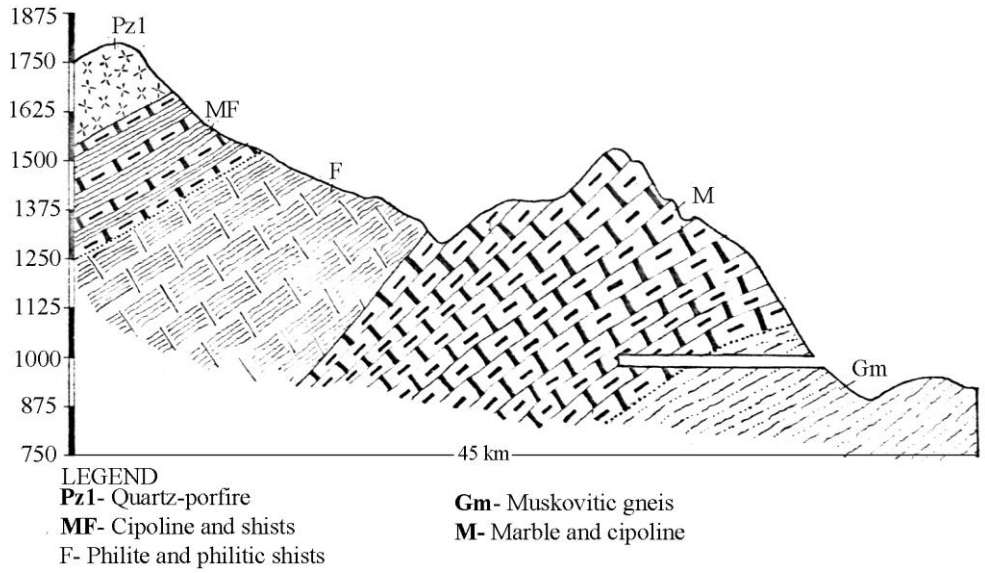

Fig. 5. Plan of the catchment gallery in muscovite gneisses and marbles and cipolines on the Cici hill near Smrdliva Voda.

SUMMARY

The paper gives the results of the hydrogelogical investigations carried out in Mt. Kozuf aiming at better water supply of Gevgelija. Data indicate that the best solutions are the underground waters of the karst springs formed in karstified Triassic limestones in the Sermenin and Huma sites situated in Precambrian marbles and cipolines in the Cici hill near Smrdliva Voda.

Catchment of underground waters should be done with the construction of captures for the Huma 1 and 2 and Sermenin springs. Possible solution also is the construction of a catchment gallery in the marbles and cipolines in the Cici hill near Smrdliva Voda.

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R e z i m e

HIDROGEOLO[KI ISTRA@UVAWA NA PLANINATA KO@UF ZA VODOSNABDUVAWE NA GEVGELIJA

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Klu~ni zborovi: trijaski bankoviti i masivni varovnici, karstni izdani, izvori{te, Huma 1, Huma 2, Sermenin, Gevgellija.

Vrz osnova na strukturniot tip na poroznost vo ramkite na istra`uvaniot teren se zastapeni slednite tipovi na izdani: freatski, slo`eni, puknatinski i karstni.

Hidrogeolo{kite istra`uvawa poka`uvaat deka uspe{no re{avawe na problemot za vodosnabduvawe na Gevgelija so kvalitetna planinska ~ista voda mo`e da se re{i so iskoristuvawe na podzemnite vodi od karstniot tip na izdani formirani vo karstificiranite trijaski bankoviti i masivni varovnici i prekambriskite mermeri i cipolini.